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OPTICAL GENERATION USING DIARYL BUTADIENE SOLUTIONS,(U)
APR 78 M I DZYUBENKO, A M KOROBOV

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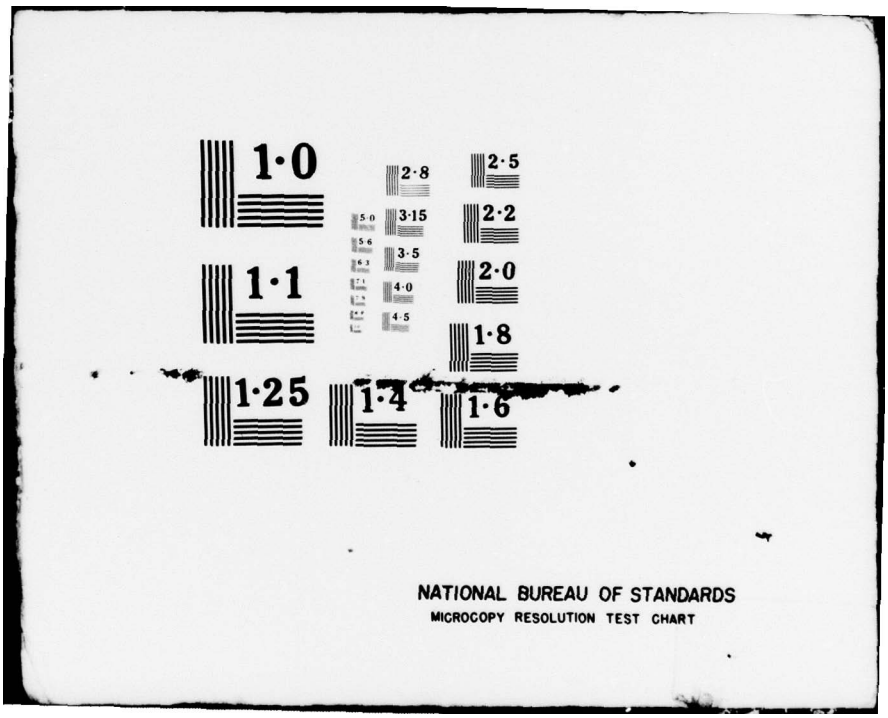
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by

M. I. Dzyubenko, A. M. Korobov, et al.

EDITED TRANSLATION

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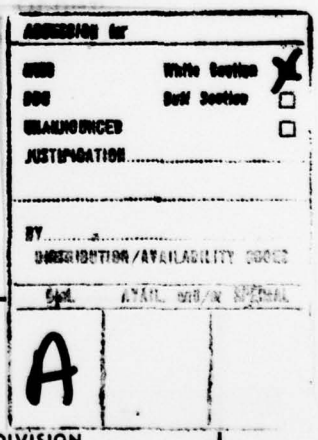

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О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ë in Russian, transliterate as yë or ë.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

OPTICAL GENERATION USING DIARYL BUTADIENE SOLUTIONS

M. I. Dzyubenko, A. M. Korbov, I. G. Naumenko, N. I. Ganushchak, and V. A. Vengrzhanovskiy

Earlier works [1, 2] reported the obtaining of forced emission of the solutions of the various classes of organic dyes when they were excited by monopulses of solid-state lasers and by the emission of flash lamps.

Here we are reporting on the stimulated emission by the solutions of new organic compounds - diaryl butadiene - and certain peculiarities of laser operations using these substances. A list of the studied compounds and also their spectral-luminescence properties

are given in the table. The diaryl butadienes are characterized by a relatively intense absorption in the near UV-region of the spectrum, by a large quantum output of fluorescence, and greater stability to the action of the UV radiation than the to dyes. Figure 1 shows a typical spectra of absorption and fluorescence. While measuring the absorption spectra the studied compounds were dissolved in hexane and while measuring the fluorescence spectra and generation they were dissolved in tolyls.

The solutions were excited by the emission of a second harmonic of a ruby laser with a modulated Q. The modulation of the ruby laser was accomplished by the rotating prism together with a saturating filter, which made it possible to obtain a more stable power of emission. The laser emission was transformed into an emission of second harmonic by the KDP crystal. The power of emission of the second harmonic was approximately 5 MW. Filter FS-7 was placed between the cuvette and the KDP crystal which absorbed the emission of the main frequency of the ruby.

Tolyl solutions of diaryl butadiene were poured into a rectangular cuvettes of various dimensions. In the experiments on the reconstruction we used the cuvettes in which one or both (front or rear) walls were slanted at Brewster's angle. The excitation was accomplished in the resonator whose optical axis was perpendicular to

the beam of pumping - a transverse version. In some cases a cylindrical lens with a focal distance of 65 mm was placed in front of the cuvette for increasing the density of the pumping power. Furthermore, to decrease the threshold power of excitation of the solution the polarization vector of pumping emission was oriented perpendicular to the axis of the resonator of a liquid laser [3]. The resonator of a liquid laser was formed by silver and dielectric mirrors with a reflection coefficient in the region of generation of 99 and 40%.

We measured the spectra of forced emission of all the substances studied under various conditions. We have discovered that the average wavelength of the generation band λ_{cp} coincides with a wavelength of the maximum fluorescence (see the table) and is independent of the power of pumping. The λ_{cp} remains constant also when we change the concentration of the solutions from 10^{-3} to 10^{-4} mole/l. Figure 2 shows the generation spectra of the solutions of substance 4 at various concentrations and excitation intensities. The variation in these parameters only led to a change in intensity of emission and to expansion or narrowing of the generation band.

The spectral properties of the laser operating on dyes were examined in [1]. It was shown that λ_{cp} in the emission spectrum of dyes is usually displaced towards the long waves from the maximum of fluorescence.

The frequency of generation was determined by the position of the maximum of the amplification coefficient. In the simplest case of the two-level model of the working substance the application coefficient

$$K_{yc}(\nu) = \sigma(\nu)\left[N_2 - N_1 e^{-\frac{h(\nu_{3,1}-\nu)}{kT}}\right], \qquad (1)$$

where N_1 and N_2 - relative population of the levels ($N_1 + N_2 = 1$); $\sigma(\nu) = h\nu/v\,NB_{12}(\nu)$ - maximum amplification coefficient; N - number of molecules of the working substance in 1 cm^3; $B_{21}(\nu)$ - Einstein's coefficient for forced emission; $\nu_{3,1}$ - frequency of a purely electron transition.

From formula (1) it is evident that the generation frequency coincides with a maximum of the fluorescence in the case when $N_2 = 1$, which is realized with infinite powers of pumping. The exponent which enters the second term of formula (1) causes a shift in the maximum $K_{yc}(\nu)$ towards the side of long waves. The role of this term can be diminished by decreasing the concentration of this solution and by increasing the intensity of excitation. However, if the Stokes shift is so large that $h(\nu_{3,1}-\nu) \gg \kappa T$, then the amplification factor

$$K_{yc}(\nu) = \sigma(\nu) N_2. \qquad (2)$$

In this case the maximum $K_{yc}(\nu)$ coincides with a maximum of the fluorescence band. With a change in the concentration of the solution, power of pumping, and Q of the resonator only the absolute value of $K_{yc}(\nu)$ will change, in other words only the width of the spectrum and the intensity of the generated emission.

We will note that the maximum width of the generation band with the excitation power used by us was approximately 60 Å, which is considerably narrower than the width of the spectrum of the forced emission of organic dyes [2].

Using this solution of substance 4 we checked the possibility of realizing a frequency reconstruction and the narrowing of the generation band by means of a prism dispersed resonator [4]. The rear wall of a rectangular cuvette made of glass K-8 was used as one of the prisms cut at the Brewster angle. In addition to this prism, between the cuvette and the rear totally reflecting mirror of the resonator we placed another one or four prisms made of glass F-1 with the refracting angle of 63° each (in these cases, the dispersion $d\beta/d\lambda$ was 18.5 and 52.2 angles s/Å, respectively). The wavelength range, in which the rearrangement was realized (in the resonators with the two or five prisms), was approximately the same (~115-170

Å). The dependence of λ_{max} on the angle of inclination of the rear mirror in both cases is close to linear. For a resonator with two prisms this dependence is shown in Fig. 3.

As seen from Fig. 3, by changing the inclination angle α of the mirror within the limits of 10' in any direction from the position corresponding to the wavelength of tuning λ_0 of the fluorescence maximum ($\alpha = 0$), λ_{max} follows the tuning wavelength λ_N. When the angles of inclination of the mirror are outside this range, at first there is a splitting of the emission spectrum (the emission spectrum consist of two bands with $\lambda = \lambda_N$ and $\lambda = \lambda_0$). Then with a further increase in α the emission is observed only at the maximum of the fluorescence band (a similar occurrence was observed by the authors of [6] for the rhodamine 6G during the rearrangement toward the long-wave side). In this case there is also a change in the direction in which the emission passes from the resonator and a sharp increase in its diversgence. The spectrum of emitted frequencies becomes wider than even in the case of nonselective resonator, its usual (see Fig. 2), for complex resonators, line structure disappears and it becomes solid. When the rear mirror was removed the emission was totally absent; however, when the front mirror was removed its intensity increased. The observed emission represents luminescence amplified with two passes (with the presence of the front mirror, and possibly due to a larger number of passes). With a sufficiently large

threshold of generation (at frequencies corresponding to the edge of the fluorescence band) the super luminescence can occur earlier than generation, which leads to even greater increase in the threshold and can even totally preclude the possibility of generation at the tuning frequency of the resonator.

We will note that the spectral width of the generation band of the prism disperse resonator decreases only by three-four times in comparison with the nonselective resonator and comprises 15-20 and 8-15 Å in the cases of two and five prisms, respectively. Figure 4 shows the dependence of the threshold pumping power on the angle of misalignment of the mirrors in a nonselective resonator. The distance between the mirrors is the same as in the case of a resonator with two prisms. We can see from Fig. 4 that the regeneration threshold has low sensitivity to the inclination of the mirrors, which is due to a large divergence of emission with a transverse version of pumping [5, 6]. Therefore, with the excitation powers which are considerably greater than the threshold power (as in our case), one should not expect a significant narrowing of the generation band by means of a prism disperse resonator. Furthermore, due to a large divergence of emission with a transversed version the duration threshold increases, which limits the range of rearrangement of the frequencies of a liquid laser.

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Summary

Optical generation is obtained in violet and near ultraviolet region by pumping solutions of diarylbutadienes with the second harmonic of a ruby laser. Independence of lasing frequency of generation conditions is explained.

Tuning range exceeding 1000 cm^{-1} was obtained with one of the investigated dyes, using a disperse prism resonator. The returning of lasing frequency to the fluorescence peak was observed with large angles of mirror inclination.

(1) Вещество	(2) $\lambda_{погл}^{макс}$, нм	(3) $\Delta\lambda_{погл}$, нм	(4) $\lambda_{фл}^{макс}$, нм	(5) $\Delta\lambda_{фл}$, нм
(6) 1. *1,4*-дифенилбутадиен-*1,3*	332	490	381	400
(7) 2. *1*-(*п*-толил)-*4*-(*п*-хлордифенил)бутадиен-*1,3*	352	570	414	540
(8) 3. 2-метил-*1*-(*п*-толил)-*4*-(*п*-хлордифенил)бутадиен-*1,3*	337	630	422	670
(9) 4. *1*-фенил-*4*-(*п*-хлордифенил)бутадиен-*1,3*	350	580	413	520
(10) 5. 2-метил-*1*-(*п*-хлорфенил)-*4*-(*п*-хлордифенил)бутадиен-*1,3*	345	690	420	540
(11) 6. *1*(*п*-хлорфенил)-*4*-(*п*-хлордифенил)бутадиен-*1,3*	355	560	425	530
(12) 7. *1*-(*о*-хлорфенил)-*4*-(*п*-хлордифенил)бутадиен-*1,3*	355	590	418	570

(13)
Примечание: $\lambda_{погл}^{макс}$ — длина волны, соответствующая максимуму полосы поглощения; $\Delta\lambda_{погл}$ — полуширина полосы поглощения; $\lambda_{фл}^{макс}$ — длина волны, соответствующая максимуму полосы флуоресценции; $\Delta\lambda_{фл}$ — полуширина полосы флуоресценции.

Table. KEY: (1) Substance, (2) λ_{absorp}^{max}, nm, (3) $\Delta\lambda_{absorp}$, nm, (4) $\lambda_{фл}^{max}$, nm, (5) nm, (6) 1,4-diphenyl butadiene, (7) 1-(n-tolyl)-4-(n-chlorodiphenyl) butadine-1,3, (8) 2-methyl-1-(n-tolyl)-4-(n-chlorodiphenyl) butadine-1,3, (9) 1-phenyl-4-(n-chlorodiphenyl) butadine-1,3, (10) 2-methyl-1-(n-chlorophenyl)-4-(n-chlorophenyl) butadine-1,3, (11) 1(n-chlorophenyl)-4-(n-chlorophenyl) butadine-1,3, (12) 1-(o-chlorophenyl)-4-(n-chlorophenyl) butadine-1,3, (13) Notation: $\lambda_{погл}^{макс}$ - wavelength corresponding to the maximum of the absorption band; $\Delta\lambda_{погл}$ - halfthwidth of the absorption band; $\lambda_{фл}^{макс}$ - wavelength corresponding to the maximum of the fluorescence band; $\Delta\lambda_{фл}$ - halfwidth of the fluorescence band.

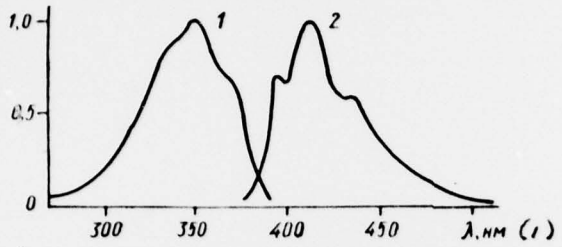

Fig. 1.

(Caption on next page)

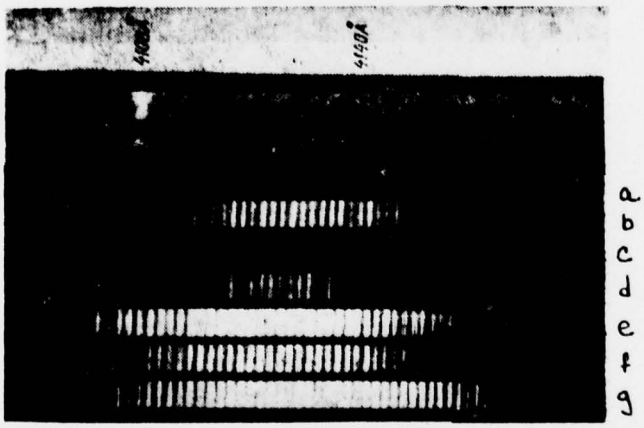

Fig. 2.

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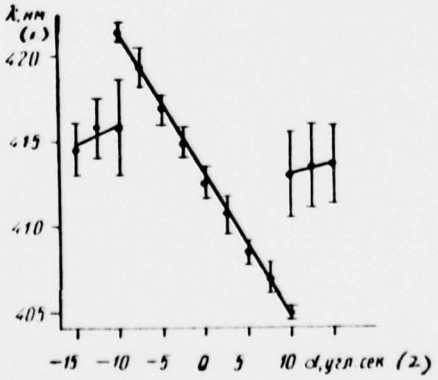

Fig. 3. (Caption on next page)

Fig. 1. Spectra of absorption (1) and fluorescence (2) of substance 4. KEY: (1) nm.

Fig. 2. Generation spectra of substance 4; a, b - c = 10^{-3} mole/l, P = 1; 5 MV; c, d, e, f, g - c = 6; 2; 1; $0.5 \cdot 10^{-4}$ mole/l, P = 5 MV.

Fig. 3. The dependence of $\lambda_{ген}$ on the angle α of the slope of the mirrors in the resonator with two prisms. The vertical segments designate the width of the generation spectrum. KEY: (1) nm, (2) α, angular s.

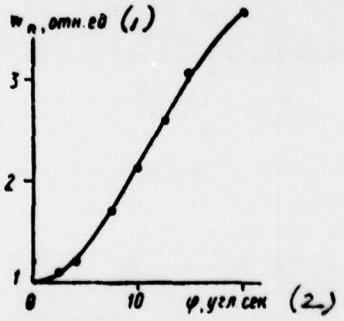

Fig. 4. Dependence of threshold pumping w_n on the angle of misalignment of the mirrors ϕ". KEY: (1) relative units, (2) angular s.

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